

# Ecological Technologies of a Chinese Traditional Folk House in Hot-Summer and Cold-Winter Zone

Mingjing Xie  
Ph.D Candidate

Guoqiang Zhang  
Professor  
Hunan University  
Changsha, China, 410082  
xmj8051@163.com

Feng Xu  
Associate Professor

**Abstract:** Regional climate should be considered in building design for energy-efficiency and environmental protection, and there are many helpful practices that are climate-responsive in traditional folk houses. Plotting of a Chinese traditional folk house located in Hunan province was conducted. Ecological technologies of the Chinese traditional folk house in the hot-Summer and cold-Winter zone were analyzed from site selection, general plane, plane design, section plane design, construction technologies, built materials, and so on. Based on the analysis results, proposals are suggested for modern residence design in China.

**Key Words:** ecological technologies; traditional folk house; hot-Summer and cold-Winter zone

## 1. INTRODUCTION

The building is root from the adverse impact of extreme natural conditions to human beings. The traditional folk house is come from the struggle and coordination between the human being and nature. The bio-climate technologies, which are adapted to the local natural conditions, were used in traditional folk house all over the word. Even in the region with extreme climate, the effective and mature technologies on climate-responsive can be found in traditional folk house. Such as the igloo of Eskimo in the Arctic Circle, building made by rammed earth technology in Middle East, building stand on stilt that made by bamboo in the South Sea Islands and so on.

Many ecological technologies were also used in Chinese traditional folk house and dwellings in urban and countryside. From the large scale such as urban planning to small scale such as windows and doors, abundant practices for climate and environment were existed in Chinese tradition folk house.

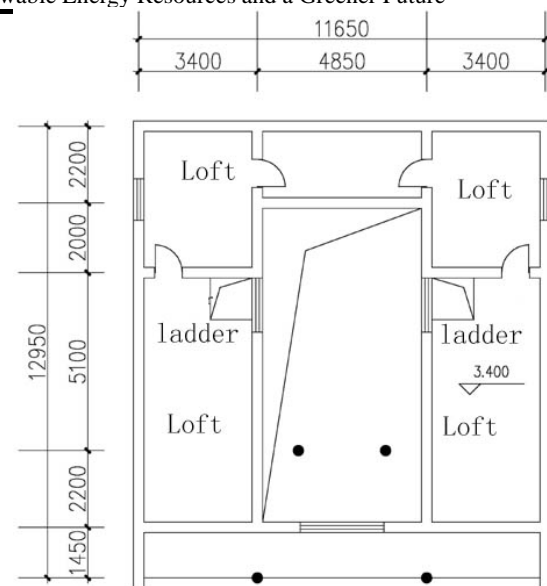
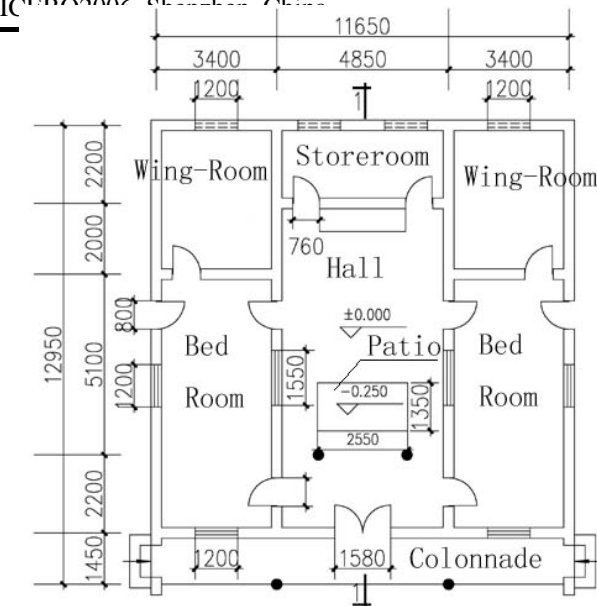
## 2. TRADITIONAL FOLK HOUSE IN HOT-SUMMER AND COLD-WINTER ZONE

The Chinese tradition folk house in the Han nationality area are all building groups with courtyard. The main characters of this kind of building are: clear traffic line; complete planning; obvious main building; building group; courtyard and so on. The application of courtyard is the most important character of traditional folk house. Because of the different placement of building group and different climate and culture, the courtyard in different zone have different form and size. The building group has a closed building space and microclimate with courtyard, and the effect of climate on main rooms will be reduced. With the change of climate zone, the size of courtyard in traditional folk house is smaller and smaller from north to south in order to adapt the differences of climate. Of cause, the traditional folk houses in different zone have different characters on placement, plane and construction and so on with the climate variety.

### 2.1 The Climate Characters in Hot-summer and Cold-winter Zone

Middle and lower reaches Yangtze River area is a typical hot-summer and cold-winter zone. This area includes Chongqing, Shanghai, Hubei province, Hunan province, Anhui province, Zhejiang province, Jiangxi province, North-east of Sichuan and Guizhou province, South of Jiangsu and Henan province and North of Fujian province.

In this zone, the monthly average temperature in hottest month is 25°C-30°C and the average relative humidity is 80%. The hottest temperature is above 40



ne of 35# house in Yangshan Village

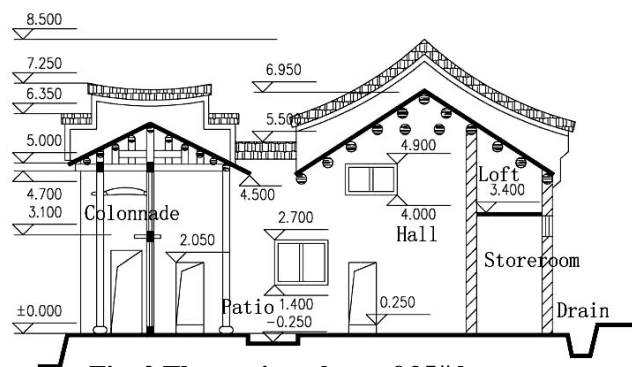


Fig. 2 The section plane of 35# house

°C. Hot and humid are the climate characters in summer. In the coldest month, the monthly average temperature is 0°C-10°C and the average relative humidity is 80%. The sunlight rate is on the low level. In this zone, the sunlight rate in winter is reduced rapidly from east to west. Cold and humid are the climate characters in winter.

Despite of the bad climate in Middle and lower reaches Yangtze River area, many technologies with zone characters, from site selection to details construction, are developed and used in traditional folk house. These technologies is useful for energy saving and environment protection. In order to analyze these technologies, plotting of a Chinese traditional folk house located in the south of Hunan province was conducted.

## 2.2 A Traditional Folk House Group: Yangshan Village

This village is located on the Guiyang County in the south of Hunan province. The village was constructed in 1497 and the area of the village is about ten thousand squares. Today, there are still sixty ancient buildings in this village and the area is about five thousand squares. The village faces to the south and there is a mountain at the north and a river around it. There are five vertical lanes and eight horizontal lanes in the village. Every family has a house with a hall, bedrooms and wing-rooms in each house. The patio is placed at the border of the houses for daylighting and natural ventilation. There are complete under-drainage facilities in this village. We chose 35# house for plotting. Fig.1 and Fig.2 is the plane, section plan of this house.

## 3. ECOLOGICAL TECHNOLOGIES OF CHINESE TRADITIONAL FOLK HOUSE IN HOT-SUMMER AND COLD-WINTER ZONE

### 3.1 Site selection



**Fig. 3 The airscape of Yangshan Village**

The site selection of Chinese traditional folk house was affected by the theory of FengShui. Wiping off the superstitious factors, the ancients observed and thought about the daylighting, heating, cooling, drainage and other habitation environment factors in site selection. It is important to analysis the earth's surface, hypsography, soil, orientation in construction of folk house. In hot-summer and cold-winter zone, the folk house always faces to the south with the mountain at the back and the water body at the front. So, the cold wind in winter from the north will be blocked by the mountain and the hot air in summer from the south will be cooled by the water body. Furthermore, the sunshine will be absorbed by the building in winter for passive heating. That is good for microclimate and indoor environment. From the Fig.3, we can see the same site selection principles that mentioned above were applied in Yangshan Village.

### 3.2 General Plane Design

In south, all the folk houses are building groups. In Yangshan Village, there are many lanes with high brick walls on both sides. The width of the lane is only 1.5m that is about 1/5 of the building height. The building density of this design is higher than 70% for land saving. In summer, the sunshine is avoided by the building for cooling. But in winter, sunshine cannot enter the lane. When Wang Fang studied the folk house in Fujian province, it was discovered that the building group can reduce the building heat gain from west side and east side and the airflow temperature will be reduced in the lane. It is good for passive cooling of the folk house in summer<sup>[1]</sup>.

### 3.3 Building Design

#### 1) The size of folk house

In hot-summer and cold-winter zone, the depth

of folk house is large, which is about 8-9m and some is more than 10m. Because of the large depth, the sunshine will be avoided to enter the center of building. This is good for passive cooling. The storey height is about 4m that is good for indoors cross-ventilation. From Fig.1 and Fig.2, we can see that the depth of 35# house is 12.95m and the storey height is 4.95m. The size of this house is larger than ordinary houses because that it is hotter in summer than other places. But Ling Borong considered that the high storey height couldn't improve the passive cooling. When he studied the folk house in south of Anhui, it was discovered that the temperature stratification is not clearly<sup>[2]</sup>. Maybe this was affected by other factors of the building. The effect of the depth and the storey height should be confirmed by more measure data.

#### 2) The design of the hall

In Chinese traditional folk house, the hall is placed at the center of the building. Hall is the core of a folk house and the activity center of family. It connects the interior spaces and exterior spaces. In hot-summer and cold-winter zone, doors of the hall, opened to the courtyard, have the same width as that of the hall. Sometimes, there are no doors of the hall towards the courtyard. This is good for daylighting and natural ventilation. From the Fig.1, we can see that the width of the hall of 35# house is 4.85m and there are no partitions towards the patio. The hall is a space connects outside as a "buffer zone" of climate.

#### 3) Halfstory and loft

In hot-summer and cold-winter zone of China, the land for house is limited. So, the loft and halfstory were built for storage and living. The windows will be setup on the roof for the loft using. This is good for ventilation. In Yangshan Village, the halfstory and loft are only built above the bedroom and wing-room. The usable floor area is increased and the effects of ventilation and thermal insulation are strengthened.

#### 4) Colonnade and arcade

In Chinese traditional folk house, the colonnades are always placed at the front and the back of houses. The depth of colonnade is about 2m. This is useful for defending the sunshine and rain in summer. In hot-summer and cold winter zone, the percentage of rainy days is about 40% of a year. The colonnade can

provide a semi-outer space for traffic and activity. In city, the folk house, beside the street, opens the arcade as footpath. The walker can walk through it in rainy and sunny days. The colonnade and arcade are transition space between indoor and outdoor spaces. It is also a “buffer zone” of climate. In 35# house of Yangshan Village, the colonnade was placed at the south of building, the depth is 1.2m and the height is 4.7m. Then the sunshine cannot enter the house in summer because of the colonnade.

#### 5) Courtyard and patio

The traditional folk house is enclosed by external wall. The courtyard is the outdoor space in folk house and is useful on adjusting microclimate, ventilation, daylighting and living. In hot-summer and cold-winter zone, the scale of courtyard is reduced as a patio and it is smaller than that in the north of China. The functions of patio are ventilation, daylighting and drainage. The area of patio is about 4-5square meters. The west and east direction of patio is long and the north and south direction is narrow. The ratio of the patio depth and building height is about 1:1. This ratio is similar to the sunshine spacing that stated now in hot-summer and cold-winter zone. The shading in summer and daylighting in winter can be confirmed by this ratio. In some places, the west and east of patio are enclosed by high walls in order to defend the sunshine from east and west. Inhabitants often plants trees in patio that can improve the microclimate. Zhao Jingyuan found that the air temperature in patio is lower than outside in summer and the air temperature variation is smaller than outside. Compared with outside, the maximum temperature in patio was postponed<sup>[3]</sup>. Lin Borong discovered that the wind speed in patio is strengthened and stable at night. But the effect of ventilation is small in the daytime<sup>[2]</sup>. These studies show that patio can strengthen ventilation at night for passive cooling. From Fig.1 and Fig.2, we can see the size of the patio of 35# house. The length of the west and east direction is 2.55m and the north and south direction is 1.35m. The height of patio is 5m. The ratio of the patio depth and building height is 1:3.7. This shows that shading in summer is more important than other factors and this can strengthen the ventilation caused by thermal press. This is

determined by the local climate (very hot in summer).

#### 6) Surface color

The different surface color has different solar energy absorption rate. In summer the low absorption rate (shallow color) can reduce the room temperature and in winter the high rate (deep color) can increase it. This theory was widely used in Chinese traditional folk house. In north area the wall building was painted with red and gray for heating in winter. In south area the building was painted with white for cooling in summer. In Yangshan Village, the wall is adobe wall with light yellow or brick wall with white color. This is in accordance with traditional methods.

#### 7) Construction methods of roof

In south of China, the pitched roof was widely used in folk house. It is good for rainproof and the spaces under the roof is used as an air heat isolation layer. In Chinese folk house, the cornice is turned up towards the sunshine. So, the roof is bended. Joseph Needham explained that the building, which the cornice is turned up, could access more sunshine in winter with low angle and defend sunshine in summer with high angle. The rain and snow can be thrown far from the building when it flows along the roof. This can protect the fabric of building<sup>[4]</sup>. Lin Borong found that in folk house with gable roof the effect of thermal isolation is very good in daytime and bad at night<sup>[2]</sup>. In Yangshan Village, the roof is gable roof and louver windows were opened at side face. It is good for ventilation and thermal isolation.

### 3.4 Construction Methods

#### 1) Wall

In traditional folk house, the architectural structure is timber structure and gable brick wall is only the envelope. In some places, the brick wall is hollow. It is good for thermal insulation. In some places, adobe or stone are used to build walls with good performance on thermal storage. Ryoza Ooka discovered that the room temperature of building is lower than outside in daytime and higher than outside at night. The maximum temperature of internal face of walls is later about 2 hours than that of external surface. This is because that the adobe walls have good performance on thermal storage and heat isolation<sup>[5]</sup>. In Yangshan Village, most of walls are

made by grey brick and few of them are made by adobe. Grey brick and adobe are both materials with large capacity on thermal storage. The indoor thermal environment is improved by them effectively.

## 2) Damp proofing methods of walls and ground

In hot-summer and cold-winter zone, the climate is humid. So, many damp proofing methods are used in traditional folk house. The building ground is connected to earth directly and the moisture is easy to get together in ground. Usually, the ground should be pounded and put the stone on it. The grout will be filled in hags. Then, put the felt on it. Finally, paint the dash. For example, a kind of folk house in Guangzhou, the thick sand-bedding course is put on the ground. Then, put the ceramic ground tile on it<sup>[6]</sup>. Furthermore, the wall foundation is made by grey brick. Brick and tile are both materials with many micropore. It can absorb moisture when the air humidity is high and give it out when the air humidity is low. The adobe wall also can absorb moisture effectively. Yan Zengfeng found that the moisture absorption content of earth building is larger than that of clay brick in the same condition and the earth building have good adjusting capability on indoor thermal and moisture environment<sup>[7]</sup>. In Yangshan Village, the ground was pounded and put the grey brick on it. The wall footing is made by granite. Based on the investigation, these methods are effective and inhabitants are satisfied with the indoor moisture environment.

## 3) Roof

In the traditional folk house, many methods are used in roof thermal insulation. The thermal insulation performance of mud or plant was used in roofs made by mud, couch grass and reed. Double layer tiled roof is another good method. The clearance between two layers is good for ventilation and heat abstraction. Ryoza Ooka found that the roof, which made by reed, have good performance on thermal insulation. In summer, the temperature of external surface of roof is 60°C and the internal surface is only 32°C<sup>[5]</sup>. In Yangshan Village, most roofs are double layer tiled roof with air space and few are made by reed for thermal insulation.

## 3.5 Fitment

## 1) Mobil fitment components

Mobil fitment components, including doors, windows and interior wall, are used in folk house for different requirements on ventilation and daylighting in different season. In Yangsha Village, the fitment components are all made by wood that are easy to assemble and unassembled. These components can be changed based on the requirements and climate.



**Fig. 4 The windows of Yangshan Village**

## 2) Hollow components

Hollowed components, including windows, doors, baluster and interior partitions, are widely used in folk house for ventilation. These components can limit the space but not block the ventilation. From Fig.4, we can see that hollowed components are widely used in folk house of Yangshan Village.

## 4. PROPOSALS FROM TRADITIONAL FOLK HOUSE TO MODERN RESIDENCE IN HOT-SUMMER AND COLD-WINTER ZONE

With the development of social, economy and architectural theory, the emphasis of residence is function zoning. But, modern architecture didn't notice the diversity in different regions. So, there are many defects in it. Traditional folk house is the best form to suit the local climate and culture because of hundreds years development in that place. The proposals from the folk house, in hot-summer and cold-winter zone, for energy saving are listed as follow:

### 4.1 Buffer Zone of Climate

In traditional folk house, there are many buffer zones, such as patio, arcade and colonnade. In modern residence, the buffer zone also exists, such as veranda. But in China, most of verandas are enclosed in order to get more area. So, in hot-summer and cold-winter zone, the veranda are all enclosed by land agent before sale or the architect will not consider it in residence. Then, there is nothing between indoor

and outdoor spaces except building envelop. The cost of cooling and heating will be increased. Furthermore, the function of self-shading of veranda is lost. The sunshine will enter the room directly.

Patio and veranda should be considered in modern residence as buffer zone of climate and add some new technologies in it. Lv Aimin considered that the patio could add adjustable glass wall on it. In summer the glass wall should be opened for ventilation and in winter it should be enclosed for passive heating<sup>[8]</sup>. Chungyoon Chun found that the veranda could reduce the air speed effectively. Veranda placed at the north of building is useful for heat preservation in winter<sup>[9]</sup>.

#### 4.2 The Utilization of Natural Ventilation

In Chinese traditional folk house, the natural ventilation is very important. But in modern residence, few of architects consider it because of the limitation of field and economical efficiency. Now, large depth and small width are widely used in the residence designs in hot-summer and cold-winter zone. Then, the land utilization rate is increased but the potential of natural ventilation is reduced. Furthermore, the sliding windows are used widely. This kind of window only has a half potential of natural ventilation compared with casement window. Using casement window and reducing the depth of building are both effective methods for ventilation. They should be used in modern residence.

#### 4.3 Sunshade Device

In traditional house, the self-shading and shading each other in building group are important. But in modern residence, shading each other cannot be implemented because of the criterion on building interval. Self-shading are also not be regarded in design stage. The awning and sunshade are combined into one device and set up by the inhabitant self. When the solar angle of incidence changed, this device loses the function of sunshade. How to shade each other on the east and west direction and how to design sunshade device should be considered more in modern residence.

#### 4.4 Pitched Roof

In modern residence, flat roof is very common. Compared with the traditional house, the indoor thermal environment of cockloft is bad because of lacking air space. Of course, there are some methods to improve this situation. But the effect is limited. In hot-summer and cold-winter zone: spring and summer is rainy; summer and autumn is hot. Traditional pitched roof is more suitable in modern residence for rain protection and thermal insulation.

### 5. CONCLUSION

Traditional folk house is the carrier for local climate and culture. Discovering the existent reasons of traditional folk house and creating the new residence form combined with the advanced culture and technologies is important. In Chinese traditional folk house, especially in hot-summer and cold-winter zone, there are many ecological technologies including energy saving, climate-responding and using local materials<sup>[10]</sup>.

These technologies are all used and improved by hundreds years. It is suitable for local climate. These technologies are all passive technologies and can be used without energy. By the research, the effects of these methods on improving indoor environment and human comfort are confirmed. These methods should be improved by modern technologies and used in modern residence. The residence with energy saving, environment protection and comfort will be created by combining the ecological technologies in traditional folk house and the theory of modern building on spaces, function and equipments.

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